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NEW OR NOTEWORTHY PORTO RICAN PYRENOMYCETES [1]

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(WITH PLATES 15 AND 16)

An increasing interest in the study of Porto Rican fungi is indicated by the fact that the Island has been visited in recent years by a considerable number of collectors. Moreover, their collections have been the subject of occasional mycological papers. The majority of these are cited in the bibliographies of Stevenson (**14**), Chardon (**3**) and Cook (**4**), while a list of the different collections is given by Chardon (**3**). An additional collection was made during the early part of 1923 by Doctor F. J. Seaver of the New York Botanical Garden and Mr. C. E. Chardon, Commissioner of Agriculture and Labor of Porto Rico, and another during the summer of 1924 by Professor H. H. Whetzel of Cornell University, Doctor F. D. Kern of Pennsylvania State College and the writer.

Recently, a number of important papers dealing with Porto Rican fungi have appeared. Spegazzini (**11**) has published an extensive work based, apparently, on the collections of Stevens; Petrak (**8**) describes many new species from specimens obtained from the collection of Fink; Miss Ryan (**9**), having made an exhaustive study of the Microthyriaceae encountered in the herbarium of Stevens, adds many new species to this group, while the writer (**21**) has published a list of the Pyrenomycetes found in the Seaver-Chardon collection including several forms

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not hitherto known from the Island. The present paper is based on material obtained from several different collections. In those cases in which the herbarium is not mentioned it should be understood that the specimens are deposited in the herbarium of Cornell University.

The writer wishes to acknowledge his obligation to Doctor N. L. Britton of the New York Botanical Garden for identification of the hosts of the fungi studied; to Doctor F. J. Seaver of the same institution for his courtesy and coöperation during the writer's three visits there; to Professor R. Thaxter who made available material in the herbarium of Harvard University; to Doctor Mel. T. Cook for specimens of *Meliola* in the herbarium of the Insular Experiment Station, Porto Rico; to Mr. C. E. Chardon for putting at the writer's disposal his entire herbarium; to Doctor F. L. Stevens of the University of Illinois who sent a collection containing twenty-three of his *Meliola* types and some of the Microthyriaceae studied by Miss Ryan; to Doctor C. Spegazzini of La Plata, Argentine, for courteous advice in correspondence; to Professor H. H. Whetzel of the Department of Plant Pathology, Cornell University, for aid and encouragement given during the progress of the work; to Mr. W. R. Fisher of the same Department for the care taken in the preparation of the photographs which illustrate the paper, and to Professor H. M. Fitzpatrick, under whose direction the investigation was carried on, for valuable suggestions and coöperation.

The system of classification proposed by Theissen and Sydow (**20**) will be followed.

HEMISPHAERIALES

MICROTHYRIACEAE

ASTERINA Lév.

ASTERINA DIPLOCARPA Cooke, Grevillea **10**: 129. 1882.
Asterina Sidae Earle, Bull. New York Bot. Gard. **3**: 310. 1905.
Asterina sidicola Ryan, Mycologia **16**: 181. 1924.

Theissen (**18**) demonstrated that *A. Sidae* Earle is identical with *A. diplocarpa* Cooke. The writer has examined type material of *A. Sidae* Earle and *A. sidicola* Ryan and has found them to be the same.

MATERIAL EXAMINED:

On *Sida carpinifolia* L.f. Rick, Fungi Austro-Americani *325* (in herbarium Harvard University); herbarium C. E. Chardon, *Earle 366;* Porto Rico Fungi, *Stevens 410* (in herbarium R. A. Toro); Explorations of Porto Rico, *Whetzel, Kern and Toro 2525, 2526, 2528.*

On *Abutilon* sp. Porto Rico Fungi, *Stevens 5642* (in herbarium R. A. Toro).

On Malvaceae. Porto Rico Fungi, *Stevens 5693, 6663a* (in herbarium R. A. Toro).

Asterina Kernii sp. nov.

Epiphyllous, effuse, forming a thin spreading carbonaceous layer covering the surface of the leaf; mycelium radiating, branches opposite or frequently unilateral, undulate; hyphae fuscous, 3–4 μ thick, septate, cells 20–25 μ long; hyphopodia opposite, sessile, rounded or slightly attenuated at the apex, 7–9 μ long, 5–6 μ wide; thiriothecia scattered, often confluent, flattened-hemispherical, 132–208 μ in diameter, composed of radiating hyphae about 3 μ thick, fimbriate, center opaque, dehiscence stellate; asci broadly elliptical, thick-walled, sessile, 42–56 x 35–46 μ, 8-spored; spores conglobate, 1-septate, smooth, 21–28 x 14 μ, hyaline when young, light brown with age, constricted at the septum; each cell subspherical, upper cell slightly broader (Pl. 15, figs. 2–3).

MATERIAL EXAMINED:

On *Brunellia comocladifolia* H. & B. Explorations of Porto Rico, *Whetzel, Kern and Toro 2481* (*Type*).

ASTERINA CORIACELLA Speg., Bol. Acad. Nac. Ci. Cordoba **11**: 560. 1889.

Referred to *Asterina solanicola* B. & C. by Ryan, Mycologia **16**: 184. 1924.

The Porto Rican material has been compared with authentic specimens of the South American species and found to be the same.

MATERIAL EXAMINED:

On *Cestrum* sp. Theissen, Decades Fungorum Brasilensium *50;* Rehm, Ascomycetes *1699b* (both in herbarium Harvard University).

On *Cestrum laurifolium* l'Her. Porto Rico Fungi, *Stevens 8533* (in herbarium University of Illinois).

On *Cestrum macrophyllum* Vent. Explorations of Porto Rico, *Whetzel, Kern and Toro 2512.*

ASTERINA SOLANICOLA B. & C., Jour. Linn. Soc. **10**: 374. 1867.
Asterina triloba Earle, Bull. New York Bot. Gard. **3**: 310. 1905.

Referred to *Asterina dipiocarpa* Cooke by Ryan. Mycologia **16**: 186. 1924.

A comparison of the type species of *A. solanicola* B. & C. with *A. triloba* Earle shows them to be the same. Theissen (**18**) noted the similarity between the two.

MATERIAL EXAMINED:

On *Solanum* sp. Wright's Cuban Fungi *738* (in herbarium Harvard University).

On *Croton discolor* W. Porto Rico Fungi, *Heller 6216* (in herbarium C. E. Chardon); Porto Rico Fungi, *Stevens 8540* (in herbarium N. Y. Botanical Garden).

MORENOELLA Speg.

Morenoella Whetzelii sp. nov.

Spots epiphyllous, 3–5 mm. in diameter; thiriothecia scattered, elongated, 150–350 x 124–140 μ, attenuated toward the ends, often curved; dehiscence by a regular longitudinal slit; mycelium radiating from each thiriothecium, distinct, more or less interwoven, fuscous, septate, branched, anastomosing, 3–4 μ thick; hyphopodia alternate, 3–4-lobed, sessile, 9–10 x 12 μ; asci broadly ovate, sessile, thick-walled, rounded at the apex, tunicated at the base, 39–45 x 27–31 μ, 8-spored; spores inordinate, unequally 1-septate, 21–24 x 7–9 μ, hyaline when young, fuscous with age, slightly constricted at the septum; lower cell broader, spherical; upper ellipsoid (Pl. 16, figs. 6, 14, 19).

MATERIAL EXAMINED:

On *Securidaca volubilis* L. Explorations of Porto Rico, *Whetzel, Kern and Toro 2483* (*Type*).

HEMISPHAERIACEAE

MICROPELTIS Mont.

MICROPELTIS ALBO-MARGINATA Speg., Bol. Acad. Nac. Ci. Cordoba **11**: 572. 1889.

Although no material has been available for comparison the Porto Rican specimen agrees well with the original description. The species has not been reported before from the Island (Pl. 16, figs. 10–11).

MATERIAL EXAMINED:

On unknown host. Explorations of Porto Rico, *Seaver and Chardon 1712*.

Scolecopeltis Speg. char. emend.

Thiriothecia dimidiate, shield-shaped, superficial; asci 2–8-spored; spores filiform, several septate; paraphysoid tissue present or absent.

The genus *Scolecopeltis* was founded by Spegazzini (**10**) and was originally placed by him in the Microthyriaceae. In a revision of this family v. Höhnel (**24**) excludes the genus and places it among the shield-shaped Sphaeriaceae, basing the change on the absence of the inverse-radiate character of the perithecium. He (**22**) established the genus *Scolecopeltopsis* v. Höhn. as a member of the Hypocreaceae with the characters of *Scolecopeltis* Speg. Theissen and Sydow (**20**) disregard the genus and cite the name as a synonym of *Scolecopeltis* Speg.

Thiessen (**16**) considering the shield-shaped character of the perithecium as of essential taxonomic significance grouped all the forms with this structure in the single order Hemisphaeriales. He recognized three families: Microthyriaceae, with inverse-radiate perithecial membranes; Trichopeltaceae, with membranes formed through thickenings of the vegetative thallus, and Hemisphaeriaceae, with shield-shaped membranes lacking the inverse-radiate character. He transferred the genus *Scolecopeltis* Speg. to the last family and placed it next to *Micropeltella* Sydow.

The type species of the genus, as well as the majority of the other described species, lacks paraphyses. However, Sydow (**15**), v. Höhnel (**23**) and others have included in the genus species

with paraphyses. The writer also has encountered species which are paraphysate. Theissen (**17**) points out that the ends of the hyphal branches in this group of fungi sometimes pass between the asci giving them an appearance of having paraphyses. In this connection he says: "*jedenfalls kann man dann nicht zwischen Arten mit untypischen Paraphysen und solchen ohne Paraphysen wieder eine generische Grenze ziehen, da diese Grenzen unfassbar sind.*" Arnaud (**1**) also found that paraphyses in this group are not homologous with the paraphyses of the Sphaeriales and Discomycetes but that they are instead sterile hyphae arising from the stroma. For this reason he named them "tissu-paraphysoide." Since their presence or absence does not furnish a sufficiently important character to justify the establishment of a new genus, the above emended description is proposed.

KEY TO PORTO RICAN SPECIES

Paraphysoid tissue absent.
- Thiriothecia less than 500 μ in diameter.
  - Spores not exceeding 60 μ in length ..... *S. pachyasca.*
  - Spores often exceeding 60 μ in length ..... *S. longispora.*
- Thiriothecia often exceeding 500 μ in diameter.
  - Spores 100–120 μ long ..... *S. portoricensis.*
  - Spores 140–150 μ long ..... *S. micropeltiformis.*

Paraphysoid tissue present.
- Thiriothecia less than 500 μ in diameter ..... *S. Cestri.*
- Thiriothecia often exceeding 500 μ in diameter.
  - Spores less than 120 μ long.
    - Thiriothecia 400–500 μ in diameter ..... *S. Ionopsidis.*
    - Thiriothecia 500–800 μ in diameter ..... *S. Ingae.*
  - Spores reaching 135 μ in length ..... *S. Chardonii.*

SCOLECOPELTIS PACHYASCA Speg., Bol. Acad. Nac. Ci. Cordoba **26**: 353. 1923.

This fungus is reported on leaves of *Coccolobis laurifolia* Jacq. No material has been available for study.

Scolecopeltis longispora (Earle) comb. nov.

Micropeltis longispora Earle, Bull. New York Bot. Gard. **3**: 311. 1905.

The spores here are about the same size as those of *S. pachyasca* as figured by Spegazzini (**11**) but differ in that they do not fall apart at the septa at maturity. The presence of a halo around the thiriothecium seen here is absent in *S. pachyasca*.

MATERIAL EXAMINED:

On *Coffea arabica* L. Porto Rico Fungi, *Heller 6349* (in herbarium N. Y. Botanical Garden).

SCOLECOPELTIS PORTORICENSIS Speg., Bol. Acad. Nac. Ci. Cordoba **26**: 352. 1923.

This fungus is reported from leaves of *Canella Winterana* (L.) Gaert. No material has been seen.

Scolecopeltis micropeltiformis sp. nov.

Thiriothecia epiphyllous, evenly distributed over the surface of the leaf, numerous, not confluent, blue-black, 500–550 μ in diameter; ostiolum circular, 20–25 μ in diameter; asci ellipsoid, at the apex rounded and thick-walled, 150–165 x 38–42 μ, 8-spored, short pedicellate, pedicel about 6 μ long; spores filiform, thick-walled, parallel or inordinate, slightly shorter than the ascus, 140–150 x 5–7 μ, 13–17 septate, often separating into two equal segments, hyaline (Pl. 15, fig. 5).

MATERIAL EXAMINED:

On *Casearia sylvestris* Sw. Explorations of Porto Rico, *Whetzel, Kern and Toro 2513* (*Type*).

Scolecopeltis Cestri sp. nov.

Thiriothecia hypophyllous, scattered, black at center, paler toward the edges, 300–425 μ in diameter, circumscribed by an inconspicuous hyaline zone; ostiolum circular, 30–40 μ in diameter; asci cylindric, 117–122 x 31 μ, 5–6-spored, thick-walled at the apex, cuneiform at the base and terminating in a short pedicel 4–6 μ long; spores parallel, filiform, thick-walled, 110–115 x 4–6 μ, 11–18 septate, hyaline, frequently separating into unequal segments; cells subequal in size with the end cells pointed; paraphysoid tissue present.

Associated with *Aulographum Cestri* Ryan.

MATERIAL EXAMINED:

On *Cestrum* sp. Porto Rico Fungi, *Stevens 7576* (*Type*) (in herbarium University of Illinois).

Scolecopeltis Ionopsidis sp. nov.

Thiriothecia amphigenous, abundant, scattered, black at center, paler toward the edges, 420–504 μ in diameter, circum-

scribed by a hyaline zone 15–30 μ wide; ostiolum round to slightly angular, 30–40 μ in diameter; asci sub-cylindric, often curved, 90–118 x 20–25 μ, 6–8-spored, at the apex rounded and thick-walled, at the base cuneiform and terminating in a small pedicel 5 μ long; spores parallel or inordinate, filiform, hyaline, thick-walled, 80–115 x 3–5 μ, 13–15 septate, easily separating into unequal segments 6–20 μ long; paraphysoid tissue present.

MATERIAL EXAMINED:

On *Ionopsis utricularioides* (Sw.) Lindl. Explorations of Porto Rico, *Whetzel, Kern and Toro 2511 (Type)*.

Scolecopeltis Ingae sp. nov.

Thiriothecia hypophyllous, scattered, light green at the center, paler toward the edges, 500–800 μ in diameter; composed of a dense weft of fungous hyphae 1 μ thick, circumscribed by a hyaline zone 30–60 μ wide; ostiolum circular, 50–60 μ in diameter; asci ellipsoid, 115–140 x 22–27 μ, 4–8-spored, round and thick-walled at the apex, thinner and sessile at the base; spores filiform, hyaline, nearly straight, thick-walled, 85–118 x 7–9 μ, 14–22 septate; end cells pointed; paraphysoid tissue present (Pl. 16, fig. 9).

MATERIAL EXAMINED:

On *Inga Inga* (L.) Britton. Explorations of Porto Rico, *Whetzel, Kern and Toro 2518 (Type)*.

On *Inga laurina* (Sw.) Willd. Explorations of Porto Rico, *Whetzel, Kern and Toro 2514, 2523*.

Scolecopeltis Chardonii sp. nov.

Thiriothecia amphigenous, mostly hypophyllous, scattered, opaque, blue-black at the center, paler toward the edges, composed of a dense weft of fungous hyphae 1–1.5 μ thick, 500–625 μ in diameter; ostiolum round, 32–40 μ in diameter; asci ellipsoid, 108–138 x 19–35 μ, 2–6-spored, the tip obtuse and thick-walled, the base sessile to short pedicellate; spores hyaline, curved, rarely straight, thick-walled, 72–135 x 6.5–7 μ, tapering toward the ends, 11–20 septate, easily separating into unequal segments; paraphysoid tissue present (Pl. 15, fig. 1 and Pl. 16, fig. 8).

MATERIAL EXAMINED:

On *Maytenus elongata* (Urb.) Britton. Herbarium R. A. Toro *59 (Type)*.

CLYPEOLUM Speg.

CLYPEOLUM SCUTELLIFORME Rehm, Hedwigia **37**: 322. 1898.

Although no material has been available for comparison the Porto Rican specimen agrees well with the original description. The species has not been hitherto reported from the Island.

Micropeltis albo-marginata Speg. also present (Pl. 16, fig. 11).

MATERIAL EXAMINED:

On unknown host. Explorations of Porto Rico, *Seaver and Chardon 1712*.

PERISPORIALES

PERISPORIACEAE

IRENE Theiss. & Syd.

Irene glabra (Berk. & Curt.) comb. nov.

Meliola glabra Berk. & Curt., Jour. Linn. Soc. **10**: 392. 1867.

The genus *Irene* was established by Theissen and Sydow (**15**) for species of *Meliola* devoid of setae. The genus is well represented in Porto Rico.

MATERIAL EXAMINED:

On *Piper aduncum* L. Porto Rico Fungi, *Heller 6204* (in herbarium C. E. Chardon).

Irene sepulta (Pat.) comb. nov.

Meliola sepulta Pat.; Stevens, Illinois Biol. Monog. **2**: 14. 1916.

MATERIAL EXAMINED:

On *Avicennia nitida* Jacq. Herbarium Insular Experiment Station *333*.

Irene irregularis (Stev.) comb. nov.

Meliola irregularis Stev., Illinois Biol. Monog. **2**: 15. 1916.

MATERIAL EXAMINED:

On *Hygrophila brasiliensis* (Spreng.) Lindl. Porto Rico Fungi, *Stevens 9283* (in herbarium N. Y. Botanical Garden).

Irene hyptidicola (Stev.) comb. nov.

Meliola hyptidicola Stev., Illinois Biol. Monog. **2**: 16. 1916.

MATERIAL EXAMINED:

On *Hyptis lantanifolia* Poit. Porto Rico Fungi, *Stevens 8130* (in herbarium C. E. Chardon).

On *Hyptis capitata* Jacq. Cornell University, Explorations of Porto Rico, *Chardon 862;* Explorations of Porto Rico, *Whetzel, Kern and Toro 2517.*

On *Hyptis atrorubens* Poit. Explorations of Porto Rico, *Whetzel, Kern and Toro 2520.*

Irene cyclopoda (Stev.) comb. nov. (Pl. 15, fig. 4).

Meliola cyclopoda Stev., Illinois Biol. Monog. **2**: 16. 1916.

MATERIAL EXAMINED:

On *Pseudelephantopus spicatus* (Juss.) Rohr. Porto Rico Fungi, *Stevens 7733* (in herbarium N. Y. Botanical Garden); *7871* (in herbarium University of Illinois).

Irene aibonitensis (Stev.) comb. nov.

Meliola aibonitensis Stev., Illinois Biol. Monog. **2**: 16. 1916.

MATERIAL EXAMINED:

On *Daphnopsis caribaea* Griseb. Porto Rico Fungi, *Stevens 8140* (in herbarium C. E. Chardon); *8479* (in herbarium N. Y. Botanical Garden).

Irene Perseae (Stev.) comb. nov.

Meliola Perseae Stev., Illinois Biol. Monog. **2**: 17. 1916.

Spegazzini (**12**) refers to *Meliola Perseae* forma *setulifera* a specimen (Ravenel, Fungi Am. Exsicc. *82*) which he examined from material collected in Florida. He makes the statement that certain species of *Meliola* may sometimes have setae and sometimes not, depending upon whether the fungus is hypophyllous or epiphyllous. This fact, however, can hardly be held to invalidate the genus *Irene.*

MATERIAL EXAMINED:

On *Persea Persea* (L.) Cockerell. Porto Rico Fungi, *Stevens 8212* (in herbarium N. Y. Botanical Garden).

Irene Laguncullariae (Earle) comb. nov.

Meliola Laguncullariae Earle, Muhlenbergia **1**: 11. 1901.

MATERIAL EXAMINED:

On *Laguncularia racemosa* (L.) Gaert. Porto Rico Fungi, *Heller 4361a* (in herbarium N. Y. Botanical Garden); Porto Rico Fungi, *Stevens 1364* (in herbarium C. E. Chardon).

Irene longipoda (Gaill.) comb. nov.

Meliola longipoda Gaill., Bull. Soc. Myc. Fr. **8**: 178. 1892.

MATERIAL EXAMINED:

On *Cordia* sp. Porto Rico Fungi, *Stevens 7472* (in herbarium C. E. Chardon); Cornell University, Explorations of Porto Rico, *Whetzel and Olive 610*.

On *Cordia nitida* Vahl. Porto Rico Fungi, *Stevens 9329* (in herbarium University of Illinois).

On *Varronia corymbosa* (L.) Desv. Explorations of Porto Rico, *Whetzel, Kern and Toro 2516*.

Irene portoricensis sp. nov.

Epiphyllous, forming circular spots 0.5–1.5 mm. in diameter, composed of a closely adhering mat of mycelial threads; mycelium septate, tortuous, dark brown, hyphae 150–250 μ long, 6–7 μ wide; capitate hyphopodia numerous, alternate or unilateral, sessile, globose, 2–6 per cell, 12–14 μ in diameter; mucronate hyphopodia opposite, bottle-shaped, light brown, 19 μ long; perithecia black, globose-applanate, 2–8 in each spot, arranged in a circle, 77–150 μ in diameter, rough; asci evanescent; spores cylindrical-ellipsoidal, 4-celled, constricted at septa, 33–35 x 14–16 μ, brown; end cells sub-equal, obtuse, middle cells equal (Pl. 16, figs. 15–16).

MATERIAL EXAMINED:

On *Acnistus arborescens* (L.) Schlet. Explorations of Porto Rico, *Whetzel, Kern and Toro 2527 (Type)*; Cornell University, Explorations of Porto Rico, *Chardon 866*.

Irene Melastomacearum (Speg.) comb. nov.

Meliola Melastomacearum Speg., Bol. Acad. Nac. Ci. Cordoba **11**: 495. 1889.

MATERIAL EXAMINED:

On *Clidemia hirta* (L.) D. Don. Porto Rico Fungi, *Stevens 9479* (in herbarium Insular Experiment Station); Cornell University, Explorations of Porto Rico, *Chardon 871;* herbarium R. A. Toro *30.*

On *Miconia prasina* (Sw.) P. DC. Explorations of Porto Rico, *Whetzel, Kern and Toro 2522.*

On *Miconia laevigata* (L.) DC. Explorations of Porto Rico, *Whetzel, Kern and Toro 2524.*

Irene glabroides (Stev.) comb. nov.

Meliola glabroides Stev., Illinois Biol. Monog. **2**: 18. 1916.

MATERIAL EXAMINED:

On *Nectandra patens* (Sw.) Griseb. Porto Rico Fungi, *Stevens 4852* (in herbarium N. Y. Botanical Garden).

On *Sauvagesia erecta* L. Cornell University, Explorations of Porto Rico, *Whetzel and Olive 616;* Explorations of Porto Rico, *Whetzel, Kern and Toro 2521.*

On *Valerianodes cayennensis* (L. Cl. Rich.) Vahl. Explorations of Porto Rico, *Whetzel, Kern and Toro 2515.*

IRENE TRILOBA (Wint.) Theiss. & Syd., Ann. Myc. **15**: 461. 1917.

Meliola triloba Wint., Hedwigia **25**: 95. 1886.

MATERIAL EXAMINED:

On *Pilea parietaria* (L.) Bl. Porto Rico Fungi, *Stevens 7232* (in herbarium Insular Experiment Station).

APPENDICULELLA v. Höhnel

APPENDICULELLA CALOSTROMA (Desm.) v. Höhn., Sitz. Akad. Wiss. Wien **128**: 22. 1919.

Sphaeria calostroma Desm., Bull. Soc. Myc. Fr. **4**: 1011. 1857.

Chaetosphaeria calostroma (Desm.) Sacc., Syll. Fung. **2**: 95. 1883.

Meliola manca Ell. & Mart., Am. Nat. **17**: 1284. 1883.

Meliola sanguinea Ell. & Everh., Journ. Myc. **2**: 42. 1886.

Meliola Puiggarii Speg., Bol. Acad. Nac. Ci. Cordoba **11**: 492. 1889.

Meliola rubicola P. Henn., Hedwigia **43**: 140. 1904.

Meliola calostroma (Desm.) v. Höhn., Ann. Myc. **15**: 363. 1917.

Irene manca (Ell. & Mart.) Theiss. & Syd., Ann. Myc. **15**: 461. 1917.

Irene calostroma (Desm.) v. Höhn., Ann. Myc. **16**: 213. 1918.

Irene Puiggarii (Speg.) Doidge, Trans. Roy. Soc. South Africa **9**: 122. 1919.

The genus *Appendiculella* was founded by v. Höhnel (**27**) for species formerly assigned to the genus *Meliola* Fr. which lack setae and possess vermiform perithecial appendages.

There has been great difference of opinion regarding the species of *Meliola* occurring on *Rubus* and *Myrica*. Stevens (**13**) and Doidge (**5**) claim that the specimens which they refer to *Meliola manca* Ell. & Mart. do not have the vermiform perithecial appendages which Gaillard (**7**) figures for this species. Beeli (**2**) places *M. manca* Ell. & Mart. and *M. rubicola* P. Henn. in the same section and with identical formulae, but refers *M. Puiggarii* Speg. to a different section. Ellis and Everhart (**6**) consider *M. sanguinea* Ell. & Everh. a synonym of *M. manca* Ell. & Mart. while Gaillard (**7**) adds *M. Puiggarii* Speg. to the synonymy. v. Höhnel (**25**) shows that *Sphaeria calostroma* Desm. is a *Meliola*. He (**26**) establishes the identity of this fungus with *M. manca* Ell. & Mart., *M. sanguinea* Ell. & Everh., *M. Puiggarii* Speg. and *M. rubicola* P. Henn. all of which he puts under *Irene calostroma* (Desm.) v. Höhnel.

All the specimens examined by the writer show the vermiform perithecial appendages distinctly. The ones on *Myrica cerifera* L. may however be confusing. Here though the appendages are sometimes very apparent, at others they are so poorly developed that they may be either overlooked or mistaken for the conical projections of the lower cells of the perithecium.

MATERIAL EXAMINED:

On *Rubus* sp. Desmazières, Pl. Crypt. Fr. **8**: *368*; Rehm, Ascomycetes *2132* (both in herbarium Harvard University); Flora Ludoviciana *74* (in herbarium N. Y. Botanical Garden); Porto Rico Fungi, *Stevens 8650* (in herbarium C. E. Chardon); *8892* (in herbarium Insular Experiment Station).

On *Myrica cerifera* L. Ellis N. A. F. *1292* (1 specimen in herbarium Philadelphia Academy of Sciences, 2 specimens in herbarium N. Y. Botanical Garden); Porto Rico Fungi, *Stevens 5289* (in herbarium C. E. Chardon).

Appendiculella compositarum (Earle) comb. nov. (Pl. 16, fig. 13).

Meliola compositarum Earle, Bull. New York Bot. Gard. **3**: 306. 1905.

MATERIAL EXAMINED:

On *Mikania cordifolia* (L.f.) Willd. Porto Rico Fungi, *Heller 6385* (in herbarium C. E. Chardon).

On *Eupatorium odoratum* L. Porto Rico Fungi, *Fink 182, 196* (in herbarium C. E. Chardon); Porto Rico Fungi, *Stevens 7977* (in herbarium C. E. Chardon); Explorations of Porto Rico, *Whetzel, Kern and Toro 2519.*

Appendiculella Calophylli (Stev.) comb. nov.

Meliola Calophylli Stev., Illinois Biol. Monog. **2**: 22. 1916.

MATERIAL EXAMINED:

On *Calophyllum antillanum* Britton (*Calophyllum Calaba* Jacq. not L.). Porto Rico Fungi, *Stevens 7059* (in herbarium Insular Experiment Station).

Appendiculella tuberculata (Stev.) comb. nov.

Meliola tuberculata Stev., Illinois Biol. Monog. **2**: 22. 1916.

MATERIAL EXAMINED:

On unknown host. Porto Rico Fungi, *Stevens 7742* (in herbarium N. Y. Botanical Garden).

Appendiculella arecibensis (Stev.) comb. nov. (Pl. 15, fig. 7).

Meliola arecibensis Stev., Illinois Biol. Monog. **2**: 23. 1916.

MATERIAL EXAMINED:

On *Acalypha bisetosa* Bert. Porto Rico Fungi, *Stevens 365a* (in herbarium University of Illinois); *6547* (in herbarium N. Y. Botanical Garden).

CAPNODIACEAE

PHAEOSACCARDINULA P. Henn.

Phaeosaccardinula Seaveriana sp. nov.

Subiculum amphigenous, effuse, covering the entire upper surface of the leaf, cinereous-olivaceous; mycelium sub-hyaline, septate, moniliform, deeply constricted at the septa; cells unequal, 7–23 x 6–8 μ; perithecia scattered, superficial, globose-hemispherical, black, glabrous, 168–200 μ in diameter; asci fasciculate, broadly-clavate, sessile, thin-walled, 60–70 x 22–30 μ, mostly 4-spored, never 8-spored; spores inordinate, ellipsoid-elongate, muriform, with 4–7 transverse and 2–4 longitudinal septa, thin-walled, 39–45 x 16–18 μ, hyaline (Pl. 16, fig. 12).

MATERIAL EXAMINED:

On *Erythrina glauca* Willd. Explorations of Porto Rico, *Seaver and Chardon 1316* (*Type*).

POSITION DOUBTFUL

TRICHOTHYRIACEAE

TRICHOTHYRIUM Speg.

TRICHOTHYRIUM COLLAPSUM (Earle) Theiss., Ann. Myc. **15**: 488. 1917.

Pseudomeliola collapsa Earle, Bull. New York Bot. Gard. **3**: 309. 1905.

MATERIAL EXAMINED:

On *Meliola* sp. on *Potomorphe peltata* (L.) Miq. Porto Rico Fungi, *Heller 6400* (in herbarium N. Y. Botanical Garden).

TRICHOTHYRIUM DUBIOSUM (Bom. & Br.) Theiss., Beih. Bot. Cent. **32**: 8. 1914.

Asterina dubiosa Bom. & Br., Bul. Soc. Bot. Belgium **32**: 157. 1896.

This agrees well with the description given by Theissen (**19**). The species has not been reported before from the Island (Pl. 16, fig. 17–18).

MATERIAL EXAMINED:

On *Irene Melastomacearum* (Speg.) Toro on *Clidemia hirta*

(L.) D. Don. Porto Rico Fungi, *Stevens 9479* (in herbarium Insular Experiment Station).

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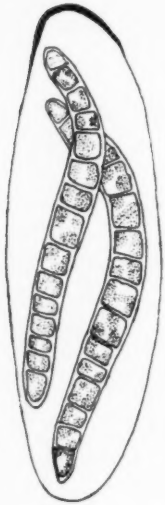

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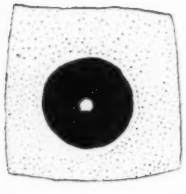

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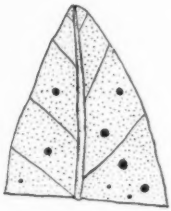

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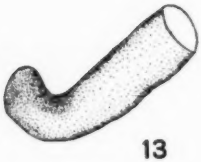

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EXPLANATION OF PLATES

PLATE 15

Fig. 1. *Scolecopeltis Chardonii.* Thiriothecia on leaf of *Maytenus elongata.* × 1.

Fig. 2. *Asterina Kernii.* Leaf of *Brunellia comocladifolia* showing habit of fungus. × 1.5.

Fig. 3. *Asterina Kernii.* Group of thiriothecia. Notice the stellate character of dehiscence and the small, opposite hyphopodia. × 90.

Fig. 4. *Irene cyclopoda.* Perithecium and mycelium. Setae lacking. × 95.

Fig. 5. *Scolecopeltis micropeltiformis.* Section of a thiriothecium showing its characteristic structure. × 95.

Fig. 6. *Morenoella Whetzelii.* A thiriothecium with radiating mycelial threads. × 90.

Fig. 7. *Appendiculella arecibensis.* A single vermiform perithecial appendage. × 90.

PLATE 16

Fig. 8. *Scolecopeltis Chardonii.* Ascus and two spores. × 450.

Fig. 9. *Scolecopeltis Ingae.* Diagrammatic sketch of a piece of leaf of *Inga Inga* showing a thiriothecium surrounded by a hyaline zone.

Fig. 10. *Micropeltis albo-marginata.* Ascus and eight spores. × 450.

Fig. 11. *Clypeolum scutelliforme* and *Micropeltis albo-marginata.* Tip of a leaf of an unknown host showing six thiriothecia of the former and near the lower margin three of the latter. × 1.

Fig. 12. *Phaeosaccardinula Seaveriana.* Two spores. × 450.

Fig. 13. *Appendiculella compositarum.* A perithecial appendage. × 450.

Fig. 14. *Morenoella Whetzelii.* Two spores. × 450.

Fig. 15. *Irene portoricensis.* Mycelial thread with mucronate hyphopodia. × 450.

Fig. 16. *Irene portoricensis.* A spore. × 450.

Fig. 17. *Trichothyrium dubiosum.* Two spores. × 450.

Fig. 18. *Trichothyrium dubiosum* showing habit of fungus on mycelium of *Irene Melastomacearum.* × 450.

Fig. 19. *Morenoella Whetzelii.* An ascus and eight immature spores. × 450.

THE LIFE CYCLE OF THE RUST ON FLY POISON, CHROSPERMA MUSCAETOXICUM

C. R. Orton and Freeman Weiss[1]

(With Plate 17 and 1 Text Figure)

In 1920 Mr. N. R. Hunt collected a rust on "fly poison," *Chrosperma* (Amianthium) *muscaetoxicum* (Walt.) Kuntze (text fig. 1), at Upper Lehigh, near Freeland, Pennsylvania. In looking up the literature it was found that this rust, previously collected in Pennsylvania, had been referred by Holway (1905) and Arthur (1920) to *Puccinia atropuncta*, described by Peck and Clinton (1879) on *Veratrum Woodii* from material collected at Allentown, Missouri, by G. W. Letterman. The urediniospores and teliospores of the rusts on the two hosts appear morphologically alike. The urediniospores are especially characterized by possessing two super-equatorial pores.

Holway also includes with *Puccinia atropuncta*, *Puccinia Zygadeni* Trelease on *Zygadenus elegans* and *Puccinia Melanthii* Bubák on *Veratrum* (Melanthium) *parviflorum*. Arthur (1920) on the basis of urediniospore characters also places *Uredo Schoenocauli* Ellis & Ev. on *Schoenocaulon dubium* as a synonym of *P. atropuncta*. Both authors consider this an autoecious long-cycle rust, but Holway states that "the only specimen of aecidium seen was collected at Armstrong, Iowa, on *Zygadenus elegans* by R. I. Cratty."

Following the collection by Hunt a survey of the region was made where the rust occurred rather commonly with the hope that some clue to the life-cycle might be found. In no case was there any indication of any other stages than uredinia and telia.

In the spring of 1921 another search was made for aecia on *Chrosperma* but without success. There was found, however, an aecidium on *Nabalus trifoliolatus*, which was closely associated

[1] Joint contribution from the Department of Botany, Pennsylvania State College No. 51, and the Bureau of Plant Industry, U. S. Department of Agriculture.

with the old dead leaves of *Chrosperma* which bore the telia of the *Puccinia*. The field evidence secured by Mr. Hunt and the writers indicated that the rust was probably heteroecious and steps were taken immediately to prove by means of cultures whether this was the case. The aeciospores from *Nabalus trifoliolatus* were sown in the field on *Chrosperma* growing about two miles removed from any known plants infected with the rust. No infection resulted from these tests.

FIG. 1. Photograph of raceme and leaves of *Chrosperma muscaetoxicum*, the latter bearing uredinia and telia of *Puccinia atropuncta*. Note the circular shape of the sori and the chlorotic zone surrounding them. Photograph by W. A. Kuntz, State College, Pa., Nov. 1, 1924.

Plants of *Nabalus* and *Chrosperma* were transported to the greenhouses of the Department of Agriculture in Washington, D. C., but both species failed to thrive in any but a peat soil, and they were not successfully transplanted until 1923. In the spring of 1924 very successful infections were secured at Washington on *Nabalus* by sowing teliospores from *Chrosperma* collected near Freeland in April, 1924.

Germinating teliospores were sown on *Nabalus trifoliolatus* Cass. April 15, 1924, following which pycnia appeared April 28, and aecia May 1 (Pl. 17, fig. 1). Another sowing was made April 28, 1924, with pycnia appearing May 7 followed by aecia May 9. Likewise infections followed by aecial development were secured on *Nabalus serpentarius* (Pursh) Hook. (inoculation May 8, mature aecia May 29—both on potted plants in the greenhouse and on native plants out-of-doors) but this host does not appear to be quite so congenial as the former since the development was much less luxuriant. On *Lactuca canadensis* growing outdoors only obscure purplish spots developed, but sowings on this host were made later (May 29) when the conditions were less favorable for infection. However, aecial infections on *Nabalus trifoliolatus* were secured as late as June 14 from inoculations made on May 29, pycnia appearing on June 10.

Uredinia and telia subsequently were produced on *Chrosperma*, following inoculation with aeciospores from *Nabalus trifoliolatus* (inoculation May 8, uredinia May 29), but failed to develop from inoculation with aeciospores from *N. serpentarius*.

In each instance sowings of spores were made on the original host as well as the suspected alternate host to detect any evidence of an autoecious condition, but only infection of the alternate host was successful.

This seems satisfactory proof that the rust on *Chrosperma muscaetoxicum* is heteroecious, bearing its gametophytic stage (O & I) on *Nabalus* spp. Whether the rust will infect the common *N. albus* has not been tested.

With this discovery it became necessary to determine in what way the aecia of the fly-poison rust differ from the aecia of *Puccinia hieraciata* (Schw.) H. S. Jackson (*Puccinia Opizii* Arth.), a *Carex* rust with aecia on various genera of the Cichoriaceae including *Agoseris*, *Hieracium*, and *Lactuca*. Studies were made of material in the Arthur Herbarium during June, 1924, and it was found that the authentic material of *P. hieraciata* (based on cultures) possesses aeciospores which are somewhat larger than those of the *Chrosperma* rust. The former measure 16–20 x 18–24 μ with walls about 1 μ thick. The latter measure 13–18 x 16–18 μ with walls 1–1.5 μ thick. The aecia are cupulate,

arranged in rather dense, irregular groups well represented by Plate 17, fig. 2.

The next problem was to determine the status of the aecia collected at Armstrong, Iowa, by Mr. Cratty. If these belong with *Puccinia Zygadeni*, as cited by Holway and Arthur, it is obvious that this rust is distinct from the heteroecious rust on *Chrosperma*, even though the uredinial and telial stages appear morphologically identical. Only one specimen of aecia, which has been referred to *Puccinia atropuncta*, is in the Arthur Herbarium, and a part of this collection is the one seen by Holway and already referred to. It was collected in the same region where the telia of *Puccinia Zygadeni* were collected and this fact apparently was the chief one for supposing that the two stages belonged to the same rust. Upon examining the aeciospores of the Cratty collection it was found that they measured 16–24 x 19–28 μ and had walls about 1.5 μ thick. They correspond in every way with the aecia of *Uromyces Zygadeni* Peck, which is the common *Zygadenus* rust throughout the Rocky Mountains extending to the plains in Kansas. Although this rust was not known farther east than eastern Kansas, there is no reason why it should not occur in northwestern Iowa where Armstrong is located.

Further cultures must establish the exact relationship of aecia occurring on various species of *Nabalus* and related hosts, since the aecia of the two rusts *P. hieraciata* and *P. atropuncta* possess no very remarkable dissimilarities, while striking similarities are shown in both urediniospores and teliospores. The pores in the urediniospores of both rusts number two and are superequatorial in position. The teliospores are moreover nearly identical. Apparently these two rusts indicate correlation of a sort different from the usual type described by Dietel (1897, 1918), Fischer (1898), Travelbee (1914) and others in which a short-cycle rust is correlated with a long-cycle heteroecious rust, the former appearing on the aecial host of the latter. The classical example of Dietel is *Puccinia Mesneriana* Thüm. on *Rhamnus*, correlated with *Puccinia Rhamni* (Pers.) Wettst. (*P. coronata* Corda) which has its aecial stage on *Rhamnus* spp. Both have coronate teliospores. A different sort of correlation

has been described by Orton (1912) in which both autoecious and heteroecious species of *Uromyces* are identical with species of *Puccinia* on the same or closely related hosts, differing only in the number of teliospore cells.

The correlation indicated in this paper appears unique but undoubtedly parallel cases occur. Here we have two heteroecious species *Puccinia atropuncta* and *P. hieraciata* (*Dicaeoma hieraciatum*) the former with uredinia and telia on Melanthaceae and the latter with its sporophytic stage on Cyperaceae. Both have their gametophytic stages on Cichoriaceae and very possibly both rusts may have aecia which are scarcely distinguishable on *Nabalus*.

Further inoculation experiments since the submission of this manuscript have resulted as follows:

The source of germinating teliospores was rusted *Chrosperma* collected at Freeland in April, 1925; material gathered in December, 1924, and stored out-of-doors at Washington, D. C., was successfully used as inoculum but its viability was less. Aeciospores were obtained from the aecial stage on *Nabalus* produced by inoculation with teliospores on *Chrosperma*. *Nabalus serpentarius* proved to be a thoroughly congenial host. In field inoculations upwards of 50 plants growing within a 10 foot circle about a few rusted *Amianthium* leaves became heavily infected. Similar results were obtained in an inoculation chamber, normal aecia developing in 18 days. The dentate-leaved form, described as *N. integrifolius* Cass., proved equally susceptible, as did also *N. albus* Hook. Simultaneous inoculations failed completely on *Lactuca virosa* L., *L. canadensis* L., and on greenhouse lettuce. Uredinia and telia on *Chrosperma* were produced in about 15 days from aeciospore inoculation, but simultaneous inoculation of *Veratrum viride* Art. and *Stenanthium gramineum* (Ker.) Morong were unsuccessful. Incomplete evidence points to this form being limited to *Nabalus* and *Chrosperma*.

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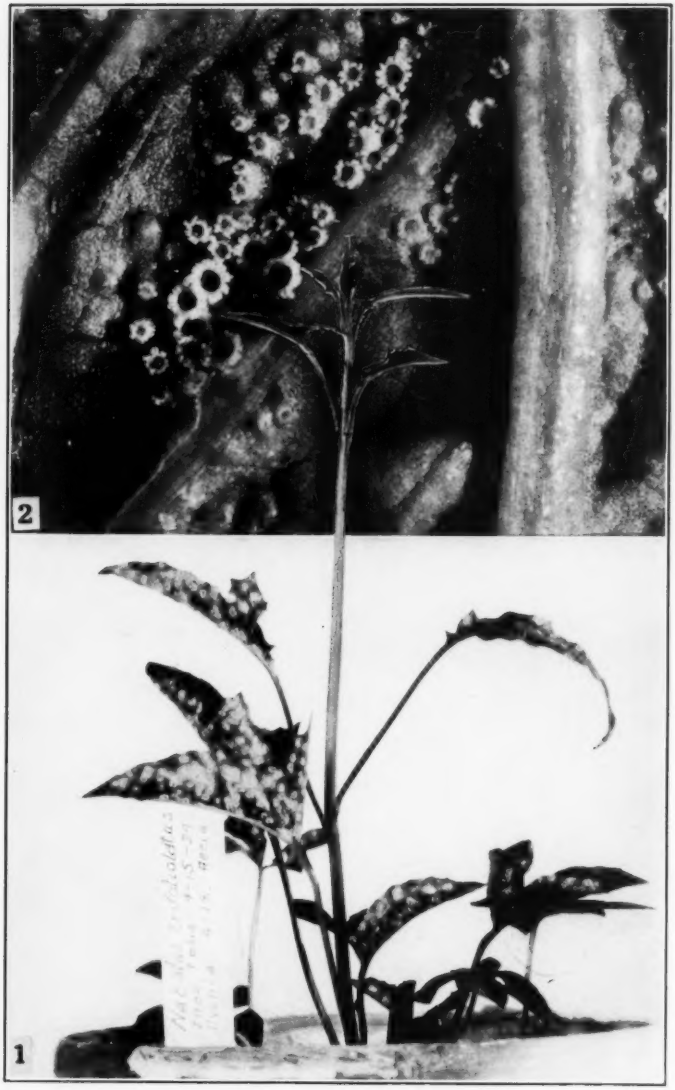


NABALUS TRIFOLIOLATUS INFECTED WITH RUST

Holway, E. W. D. North American Uredineae **1**[1]: 20. 1905.
Orton, C. R. Correlation between certain species of *Puccinia* and *Uromyces*. Mycologia **4**: 194–204. 1912.
Peck, C. H., & Clinton, G. W. Bot. Gaz. **4**: 171. 1879.
Travelbee, H. C. Correlation of certain long-cycle and short-cycle rusts. Indiana Acad. Sci. **1914**: 231–234. 1915.

EXPLANATION OF PLATE 17

Fig. 1. Potted plant of *Nabalus trifoliolatus* inoculated with germinating teliospores of *Puccinia atropuncta* from *Chrosperma muscaetoxicum* April 15, 1924. Pycnia first noted April 28 and aecia May 1. Photographed at Washington, D. C., May, 1924.

Fig. 2. Photograph of under surface of *Nabalus trifoliolatus* showing aecia with revolute and lacerate peridia. From artificially infected leaves. Photographed at Washington, D. C., May, 1924.

RELATION OF GLYCOGEN TO SPORE-EJECTION

LEVA B. WALKER AND EMMA N. ANDERSEN[1]

(WITH PLATE 18)

One of the many elusive problems concerning fungi is the source of the energy used in the ejection of their spores or spore-masses. A good opportunity to study this problem is afforded by *Sphaerobolus* which, as is well known, hurls its spore-masses farther than any other known fungus. Three forms of *Sphaerobolus* were grown in pure cultures during a period of years while studying their morphology and development. All the forms studied fruited freely, hence an abundance of material was available.

The fruit-bodies of a *Sphaerobolus*, just previous to opening, are spherical in shape, usually about 2 to 3 mm. in diameter, and more or less deeply imbedded in the surrounding mycelium or substratum. (See rounded masses in Pl. 18, figs. 2 and 4.) When mature the outer or peridial parts of the fruit-body break open on top in a stellate manner (Pl. 18, figs. 2 and 4), revealing a spherical ball, the glebal mass, on the inside. This rupture takes place early in the morning. As the morning advances a clear watery fluid accumulates around the glebal mass in the cup formed by the peridial parts. In the meantime a rupture has taken place between two layers in the peridium and the inner of these suddenly inverts itself and in so doing hurls the glebal mass to a height of over 14 feet. The inner peridial region may be seen inverted and appearing as a glistening dome above the outer peridial parts in three places in Plate 18, fig. 4. In one form studied the inner peridial layer frequently is ejected along with the glebal mass.

[1] This paper is an outgrowth of unpublished work on the morphology and development of *Sphaerobolus* that has been carried on by Miss Walker. Credit is due Miss Andersen for the microchemical work upon which this paper is based, for without her assistance and suggestions the microchemical tests could not have been made.

Three distinct regions are easily seen: first, an outer peridial region which always remains attached to the substratum and more or less deeply imbedded in it; second, an inner peridial region which at the time of discharge becomes inverted as a dome above the outer region and which by its sudden change of position hurls the glebal mass; and third, the glebal mass itself.

The outer peridial region of nearly mature fruit-bodies differs in structure in the forms studied. In Plate 18, fig. 1, a median longitudinal section of a nearly mature fruit-body of *Sphaerobolus stellatus* is shown. The outer peridial region consists of the three outer layers "*O*." The inner peridial region "*C*" is made up of the so-called "collenchyma" layer which is composed of large cells, much elongated radially, especially at the base of the fruit-body, and a "thread" layer composed of slender tangentially arranged hyphae, while the glebal mass "*G*" contains spores with intermixed hyphae and surrounded by a dense layer of pseudoparenchyma.

When the fruit-body opens, all of the peridial regions are ruptured down to the glebal region. The opening is made possible by the gelatinization of a layer of cells between the "collenchyma" layer and the glebal mass. As a result of this gelatinization the ball-like glebal mass is separated completely from its peridial cup. In the meantime another layer of cells between the inner and outer peridial regions gelatinizes and allows these two layers to separate up to the tip of the peridial points. After the discharge the peridial parts are seen in the position shown in Plate 18, fig. 3, "*C*" indicating the inner peridial region and "*O*" the outer peridial region.

Early observations upon *Sphaerobolus* indicated that the forceful ejection of the spore-mass was due to a high osmotic pressure developed in the "collenchyma" layer. It has been possible to determine by experiments that only the inner peridial region could have any part in effecting the final discharge. (This has also been confirmed by Dr. A. H. R. Buller working independently, according to his verbal statement.) An important fact about the "collenchyma" layer is that up to the time the fruit-body opens the cells are completely filled with a densely granular content which disappears during the few hours inter-

vening between the opening of the fruit-body and the discharge of the spore-mass. Before the discharge takes place, as has been noted, the "collenchyma" layer, together with a few filaments of the "thread" layer, become separated from all other regions in the fruit-body, thus making it possible to study this inner peridial region by itself. These observations lead to the belief that microchemical tests might be applied advantageously in order to determine what changes took place in the "collenchyma" layer and therefore what had given the force for the discharge. Miss Andersen became interested in the work at this point.

Our tests[2] show that the collenchyma layer before and at the time the fruit-body opens is densely filled with glycogen, as has been reported by Errera[3] and others. By the time the discharge takes place the glycogen has been transformed into sugars. (Reducing sugars were abundantly present. Maltose at least could be definitely demonstrated.) This sudden transformation of glycogen which exerts almost no osmotic pressure to sugars with their high osmotic pressure causes an expansion of these collenchyma cells which are free on their inner ends and held tightly together by the "thread" layer on their outer ends. A few of the cells of the "thread" layer also contain glycogen which is seemingly similarly transformed and by the slight swelling of these cells an added tension is developed tangentially. The sudden osmotic expansion of the cells in these two layers causes the inversion of these layers and provides the force for the discharge of the glebal mass. If a fruit-body opens when temperatures are low and the light dim glycogen is transformed to sugars so slowly that the inversion of the "collenchyma" layer takes place very gradually and the glebal mass is left in place on the upturned "collenchyma" layer. On the other hand,

[2] In testing for glycogen, the iodine test was used almost exclusively. For sugars Flückiger's reaction and the phenylhydrazine reaction were used. With the latter reagent frequently some difficulty was experienced in securing osazones. Hydrazones formed readily and abundantly but the osazones sometimes would form and then instead of "feathering out" more and more on standing as with pure chemicals, they would seemingly be dissolved by other substances present and disappear. The best results were obtained with the cold process.

[3] Errera, L., Sur le Glycogene chez les Basidiomycetes, Rec. de l'Inst. Bot., Bruxelles **1**: 95. 1885.

if the temperature is at about 90° F. at the time of the opening of the fruit-body and the light is bright, these changes take place so suddenly that the glebal mass may be hurled over fourteen feet vertically into the air. It is interesting to note that the opening of the fruit-body itself is due to the change of glycogen to sugars in an outer layer.

The very definite relation between the transformation of glycogen to sugars and its efficiency in bringing about the ejection of the spore-mass in *Sphaerobolus* led to tests on other fungi to see to what extent such phenomena may occur elsewhere. Young asci and young basidia were found to contain glycogen, and as is well known, it disappears just before the discharge and sugars are present afterward. In long slender asci such as found in *Peziza vesiculosa* the glycogen is usually confined to the part of the ascus below the spores while in broader asci it surrounds the spores also. We have not been able definitely to localize the sugars in sections but in young hymenia before the spores were discharged no sugars were found, while in older hymenia sugars were present. The amount of glycogen in the young asci and basidia varied greatly in different species examined, and although no tests were made to establish the fact, it appears that the amount of gycogen present determines the distance to which the discharge may take place. For example, the asci of Ascobolaceae examined, such as *Lasiobolus*, are much more densely filled with glycogen than those of *Peziza vesiculosa*, *P. badia*, or *Sarcoscypha coccinea*, and these last contain very much more glycogen than species of *Lachnea* and *Humaria* examined. The asci of Pyrenomycetes examined contain only traces of glycogen. In general basidia contain less than asci. In *Pilobolus* glycogen is present in the young sporangiophore and disappears largely before the discharge but no reducing sugars could be definitely demonstrated.

Aside from the rôle of glycogen when transformed into sugars in bringing about spore-ejection similar transformations take place in other parts of fruit-bodies and cause the sudden enlargement of cells that results in the expansion of the fruit-body. For instance, in small, dung inhabiting *Coprini* just before the elongation of the stipe, glycogen is present and disappears during

the enlargement of the cells that produce elongation. The same conditions are noted before and during the expansion of the pileus, trama, etc. One of the most definite tests made was on a young ascocarp of *Peziza vesiculosa* before any spores had matured. All of the smaller cells of the fruit-body were densely filled with glycogen while the larger cells were filled with a reducing sugar. Sections that had been tested by Flückiger's test were washed and then tested for glycogen and very definite localization obtained.

That glycogen is readily changed to maltose if diastase is present is a quite well-established chemical fact, according to Haas and Hill.[4] In our work with *Sphaerobolus* maltosazones were always found. Other sugars may have been present but no dependable results were secured. It seems probable from our tests that different sugars may be formed by different fungi and by the same fungus under different conditions.

As a result of his extensive work on glycogen in all groups of fungi, Errera[5] concludes that glycogen is the reserve carbohydrate of fungi, comparable to starch in higher plants. He observed the transformation of glycogen into sugars during the maturation of tissues, asci, etc. Since glycogen disappears from fungus cells during their enlargement he concludes[6] that it supplies the cell with the substances necessary for growth.

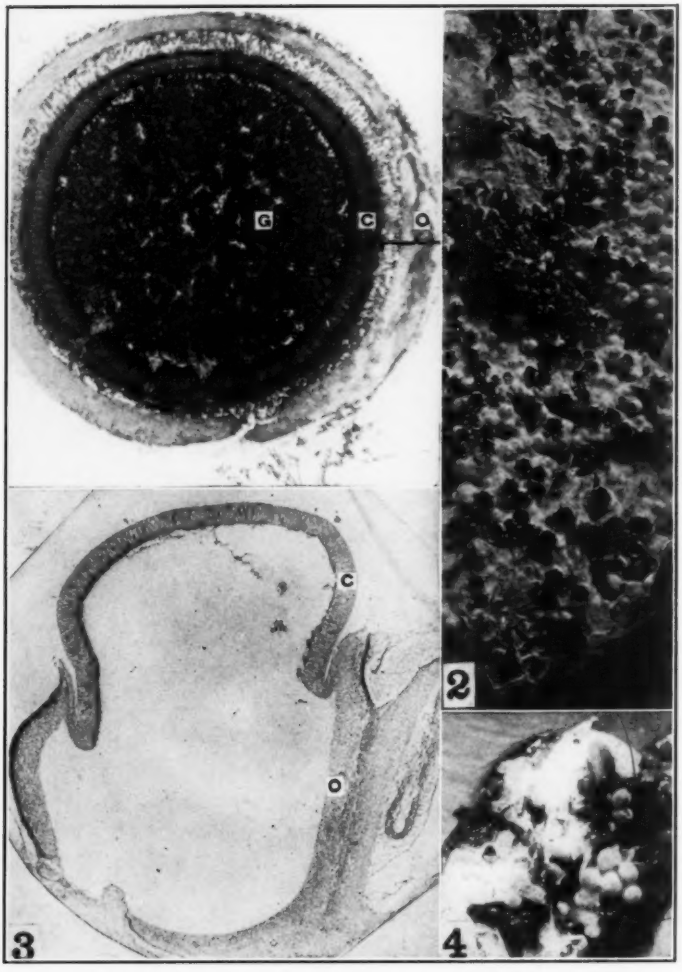
It seems very probable that Errera is correct in believing that glycogen may serve as a reserve carbohydrate, comparable to starch, yet he sets forth little experimental evidence to substantiate his assumption. On the other hand, Miss Ternetz,[7] in her work on *Ascophanus*, shows that the glycogen stored by that fungus cannot be used for its nutrition when no other food is available, at least under the conditions tested. We have no evidence along this line but we feel that we have evidence that one of the primary functions of glycogen, when transformed into sugars, is to create osmotic pressure which results in a sudden

[4] Haas, P., and Hill, T. G., An Introduction to the Chemistry of Plant Products. 3d edition. **1**: 130. 1921.

[5] Errera, L., Sur le Glycogene chez les Basidiomycetes, Rec. l'Inst. Bot., Bruxelles **1**: 1–134. 1885.

[6] Loc. cit. 122.

[7] Ternetz, Ch., Protoplasmabewegung und Fruchtkörperbildung bei *Ascophanus carneus* Pers. Jahrb. f. Wiss. Bot. **35**: 276. 1900.



SPHAEROBOLUS

enlargement of cells in vegetative tissues of fungi and is, at least in many cases, the direct cause of the forceful ejection of spores and spore-masses in reproductive parts.

The writers wish to extend grateful acknowledgment to Dr. Sophia Eckerson for reading the manuscript of this paper and to Prof. T. J. Fitzpatrick for reading of manuscript and proof.

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EXPLANATION OF PLATE 18

Fig. 1. Photomicrograph of a median longitudinal section of a nearly mature fruit-body of *Sphaerobolus*. *O*, outer peridial region; *C*, inner peridial region; *G*, glebal region. × 37.

Fig. 3. Photomicrograph of a median longitudinal section of the peridium of *Sphaerobolus* after the discharge of the glebal mass. *O*, outer peridial region; *C*, inner peridial region.

Figs. 2 and 4. Photographs of cultures of *Sphaerobolus* showing fruit bodies in various stages of development.

CLUB-ROOT OF CHINESE CABBAGE

W. H. Davis

(With 1 Text Figure)

The Host

Chinese cabbage (*Brassica Pe-tsai* Bailey) was introduced into America about 35 years ago and to-day it is one of the closest rivals of our head lettuce. Fairchild[1] has pointed out the advantage of Chinese "petsai" over head lettuce as follows:

1. The cost of production is reduced one-half.
2. It can be grown throughout the country.
3. The keeping qualities are superior.
4. Pound for pound, it may contain equal portions of the desirable food element, "fat soluble A."
5. It is more attractive in appearance.

At the present time Chinese cabbage is not extensively cultivated but, according to Fairchild, it has a future as a salad plant. However, much of the prejudice caused by the term "cabbage" should be removed and the American housewife educated to its use.

The Disease

In October 1923 the writer had occasion to remove Chinese cabbage plants from the vegetable gardens of the Massachusetts Agricultural College and transplant them in ten-inch pots for experimental work in the greenhouse. The roots of these transplanted plants contained numerous large galls similar to those on common cabbage when infected by *Plasmodiophora Brassicae* Woronin which causes club-root. A previous description of this disease on Chinese cabbage has not come to the writer's attention.

Free-hand sections of these diseased roots on Chinese cabbage showed hypertrophy of the cells in the parenchyma and the usual transitional stages between plasmodium and matured spores which are generally visible in roots parasitized by *P. Brassicae*.

[1] Fairchild, D., The Chinese Petsai as a Salad Vegetable. Jour. Hered. 9: 291–295. 1918.

One of the diseased Chinese cabbage plants of a variety known as "kinshiu" died three days after transplanting. In November, 1923 the pot containing this dead plant together with the soil was stored outdoors near the east wall of the pathologium. In September, 1924 the pot was returned to the greenhouse bench and forty-eight seeds of Chinese "wong bok" were sowed therein. The contents of this pot were subjected to the same conditions of light, heat (20° C.) and moisture as plants growing on the same bench. Sterilized and unsterilized soils from the greenhouse bench placed under the same conditions were employed in the checks.

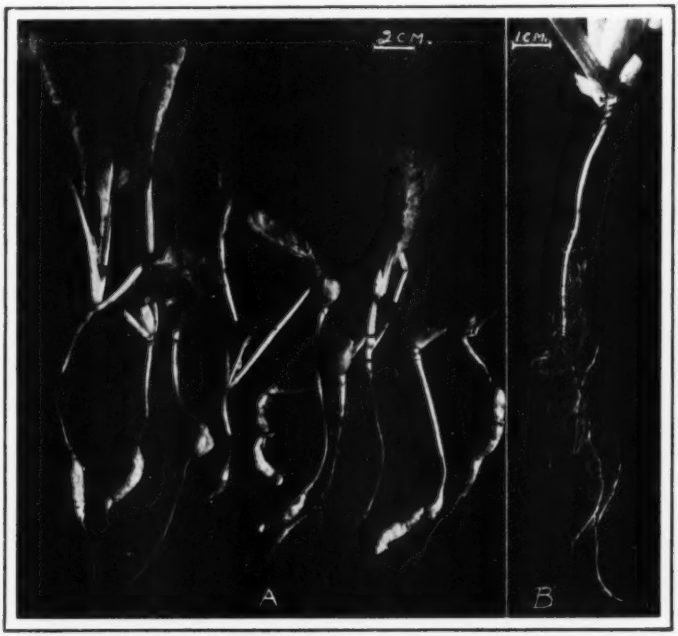

FIG. 1. Photographs of Chinese cabbage plants; A. Roots infected with *Plasmodiophora Brassicae* Woronin causing club-root; B. A healthy root.

On November 15, 1924, thirty-eight plants had developed from the forty-eight seeds and all but one showed symptoms of club-root (Text fig. 1, A). On January 15, 1925, twenty of these

plants had been removed for experimental purposes, seventeen had died and one was still alive. Each one of the thirty-eight plants was infected with *P. Brassicae*. In free-hand sections of these diseased roots, the usual hypertrophy of the cells together with the different morphological structures common to *P. Brassicae* were easily recognized. All plants in the checks appeared healthy (Text fig. 1, B). From the symptoms and spore measurements together with other details described by Woronin [2] the organism was recognized as *P. Brassicae*. Club-root was also observed on Chinese "petsai," "paoting" and "chosen."

From the above observations and experiments it is evident that Chinese "wong bok," "kinshiu," "petsai," "paoting" and "chosen" are hosts for *Plasmodiophora Brassicae* Woronin which causes the disease commonly known as club-root.

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[2] Woronin, M., Plasmodiophora Brassicae. Jahrb. f. Wiss. Bot. **11**: 548–574. pl. *19–24*. 1878.

THE INHERITANCE OF RESISTANCE OF OAT HYBRIDS TO LOOSE SMUT[1]

GEORGE M. REED

The study of the inheritance of disease resistance constitutes a problem of great economic and scientific interest and numerous investigators have contributed towards its elucidation in various groups of diseases. The present paper is concerned with studies on the inheritance of resistance to the loose smut of oats, *Ustilago Avenae* (Pers.) Jens., in a hybrid between a very susceptible variety, *Avena nuda* L. var. *inermis* (S.N. 30), and a very resistant one, *A. sativa* L. var. *Black Mesdag* (S.N. 70). Although the results here described relate to a single cross, investigations are in progress on additional ones between the same parents, as well as crosses involving other varieties.

A few results on oat smut inheritance have previously been recorded. Wakabayashi (**18**) has published some data on the behavior of the progeny of a cross between Red Rustproof and Black Tartarian to *Ustilago levis* (K. & S.) Magn., the former being resistant and the latter susceptible to the smut. No smut was observed among the F_1 and F_2 plants. In the F_3 generation, however, twelve families out of a total of ninety-five were observed to contain a few infected individuals. Barney (**1**) has recorded more extensive data on three different oat crosses. One cross involved two very resistant varieties, Fulghum and Black Mesdag; a second cross was between the resistant Burt and the susceptible Swedish Select; and the third cross was between two susceptible varieties, Turkish Rustproof and Golden Rain. Barney interpreted his results on the basis that resistance in the first cross depended upon three different factors, in the second upon two, and in the third upon only one. Reed and Stanton (**16**) have described their results with a cross between

[1] Brooklyn Botanic Garden Contributions No. 45. The writer is specially indebted to Lois Davis Van Gorden for valuable assistance in carrying on the studies and preparing the data for publication.

Fulghum and Swedish Select, the former being very resistant to both *Ustilago Avenae* and *U. levis*, while the latter is susceptible to both smuts. The behavior of the F_2 plants was not recorded but of the F_3 progeny studied, some showed a degree of susceptibility corresponding to that of Swedish Select, a few progenies showed a much greater susceptibility, while still others possessed a resistance corresponding to that of Fulghum. No correlation between morphological characters and susceptibility or resistance was observed and they conclude that it is possible to combine resistance to smut with other varietal characters of oats.

THE PARENTS AND THE F_1 PLANT

The Female Parent.—The strain of *Avena nuda* was received from Doctor Franz Bubák, then Director of the Botanic Garden, Tabor, Bohemia, in April, 1913 under the name of *A. nuda* L. var. *chinensis* Fischer. It, however, seems more properly to belong to the variety *inermis*, since there is an almost complete absence of awns of any description.

The hull-less or naked oats are distinguished from the other species of *Avena* by several characteristics: (1) The empty glumes and lemmas are very similar in texture, being thin and membranous; (2) the lemma and palea do not clasp the kernel, the latter remaining loose or free within the chaff and readily separating in threshing; (3) each spikelet of the panicle bears several flowers, varying from four to nine; (4) the rhachillas of the spikelets are much elongated so that the uppermost grains are borne well above the empty glumes.

The young stems of the strain used were erect in growth and a moderate amount of tillering occurred. The average height of the plants to the base of the panicle, grown under greenhouse conditions, was about forty inches. The leaves, light green in color, were rather narrow, the uppermost one averaging slightly more than one half inch in width.

The panicles were equilateral and compact, with a fairly large number of branches. The average length in the plants studied was nine inches. The spikelets of the panicle were many-flowered, usually four to six. The empty glumes and lemma were essentially similar in structure. The awns were absent or, at most, weak awns occurred on the basal flower of a few spikelets.

Hull-less oats have relatively little economic value, although for centuries they have been grown in western China and have served as an important source of food for the natives. In Europe and America they have been largely grown for their botanical interest. They have, however, been used in crossing with other forms of oats and various selections of hulled types from the hybrids have been made which have given rise to cultivated varieties with desirable agronomic characteristics. In recent years the hull-less Liberty oat has been developed by the Ontario Agricultural Experiment Station from a cross between Chinese Hull-less and Swedish Select. This particular variety has quite a large kernel, yields well, and promises to be of considerable economic value.

The Male Parent.—The strain of Black Mesdag was also received from Dr. Franz Bubák in March, 1914 under the name of *Avena sativa* L. var. *nigra*. The presence of numerous awns on the plant, however, suggests that it more properly belongs in the variety *montana* and appears to be identical with Black Mesdag.

The culms of the plant were erect in early growth and relatively little tillering occurred; they were large, coarse and glabrous. The average height to the base of the panicle, when grown under greenhouse conditions, was forty-two inches. The leaves were dark green, with smooth margins, the uppermost one to one and one half inches wide.

The panicles were equilateral, wide spreading and very lax, drooping or nodding from the middle outward, varying in length from fifteen to eighteen inches, with relatively few branches. The spikelets bore two grains, rarely three. The lemmas were brownish black, elongated, glabrous, with seven rather obscure nerves. Well developed awns were usually present on the lower grain of each spikelet. The bases were twisted, frequently geniculate. Occasionally a few hairs, one to two mm. long, fine and weak, occurred at the base of the outer kernel. The rhachilla of the outer grain was two to three mm. long, with long, stiff hairs.

Black Mesdag is a medium early maturing oat. To some extent it is grown by farmers but it is not regarded as having any special merit.

The F_1 Hybrid.—The F_1 plant was grown under greenhouse conditions. The young stems were erect; four stalks developed to maturity, the main stalk being thirty-eight and one-fourth inches high to the base of the panicle, with eight internodes. The leaves were dark green in color and wide, thus resembling the Black Mesdag parent.

The panicle was fifteen and three fourths inches long, spreading and drooping somewhat from the middle outwards. In general shape it resembled the Black Mesdag parent but there was a larger number of branches and spikelets. The spikelets were all many-flowered, the number of grains produced being from one to five. The empty glumes and lemmas were entirely similar to those of *Avena nuda*, pale yellow in color and membranous in texture; the paleae, however, were dark. The grains were held loosely within the glumes, readily falling out in threshing. Very weak or feeble awns were present on the basal flowers of a few spikelets. They were slightly more numerous than on the hull-less parent but no well developed awns with twisted bases were present. The plant was very fertile, approximately five hundred kernels being produced.

In general the plant resembled a somewhat more robust type of the hull-less parent. The broader leaves, the longer, more lax and drooping panicle, together with the dark color of the palea, were the most marked points of difference. It is especially noteworthy that there was a complete absence of any indication of an intermediate condition in the character of the spikelets, such as has been described by other investigators who have crossed hulled and hull-less oats.

RESISTANCE AND SUSCEPTIBILITY OF THE PARENTS TO USTILAGO AVENAE

Reed (**12**) and Reed, Griffiths and Briggs (**15**) have published extensive data on the behavior of oat varieties to both loose and covered smuts. The particular strain of *Avena nuda* (S.N. 30) used as the female parent in this cross has been grown for a number of years under very diverse conditions and its behavior towards *Ustilago Avenae* has been very fully determined, especially with reference to the Missouri strain of this smut as

described by Reed (**13**). Under field conditions, 4,592 plants have been grown over a period of eleven years; 3,284 of these plants, or 71.5 per cent, were infected. It would not be unusual to find all the plants in the row entirely smutted, although frequently one or more escaped. In the greenhouse, where the conditions in general were more favorable for infection by the smut, higher percentages of infected plants have been obtained. In various experiments, 297 plants have been grown, of which 260, or 87.5 per cent, have been infected. The variety Black Mesdag (S.N. 70) presents a complete contrast to the hull-less oat with reference to its behavior to *Ustilago Avenae*, as it has shown a remarkable degree of resistance. Under field conditions, over a period of nine years, 4,270 plants have been grown, of which only four have been infected. In the greenhouse, 295 plants have been grown and none have been infected. These figures include the data published in the papers just referred to as well as additional data more recently obtained.

EXPERIMENTAL RESULTS WITH THE F_2 GENERATION

The seed which developed into the F_1 plant was not inoculated for the obvious reason that, if infection occurred, seed formation would be prevented and further continuance of the experiment made impossible. The fact that infection with this smut takes place in the seedling condition, and that, if it does occur, it is likely to result in the complete destruction of the grain, makes necessary certain modifications in the procedure of analyzing the inheritance of resistance. Consequently, in the F_2 generation, as well as the subsequent ones, only a portion of the seed was inoculated, additional uninoculated plants being grown with a view to obtaining sufficient plants for the study of spikelet and other characters and for propagation in successive generations.

Bartholomew and Jones (**2**), and Reed and Faris (**14**) have determined the influence of certain environal factors on infection of oats by smuts. It has been found that a relatively dry soil and a temperature of about 20° C. are very favorable for infection of oats by both loose and covered smut. Although infection takes place over a comparatively wide range of temperature and moisture the highest percentages are secured under the particular

conditions just mentioned. In the experiments with the hybrid the dry seed was inoculated by dusting with the dry spores. The seed was then germinated in sand with a low percentage of moisture and either in the constant temperature tank at 20° C. or in the greenhouse where the temperature averaged near to 20° C. In some cases the seedlings were transplanted and grown to maturity in the greenhouse, while in other experiments the germinated seedlings were transplanted to the field where they matured. In all the plantings of the hybrids inoculated seed of both parents was also grown for the purposes of direct comparison.

Eighty-two F_2 plants matured from inoculated F_1 seed and accordingly had a chance to become infected in the seedling stage and develop the characteristic smut lesions in the adult plant. Twenty-five of these plants were grown to maturity in the greenhouse and the remaining fifty-seven in the field. The data on the infection of these plants, as well as the two parents grown simultaneously, are shown in Table I.

TABLE I

DATA OBTAINED WITH INOCULATED F_2 PLANTS

	Hybrid			*Avena nuda*			Black Mesdag		
	No. plants	No. inf.	Per cent inf.	No. plants	No. inf.	Per cent inf.	No. plants	No. inf.	Per cent inf.
Greenhouse ...	25	5	20.0	30	27	90.0	25	0	0
Field.....	57	16	28.0	143	137	95.8	75	0	0
Total.....	**82**	**21**	**25.6**	**173**	**164**	**94.7**	**100**	**0**	**0**

As seen from the table, twenty-one plants out of a total of eighty-two, constituting 25.6 per cent, were infected. Under the same conditions, the resistant parent, Black Mesdag, gave one hundred plants, none of which were infected. On the other hand, one hundred seventy-three plants of the susceptible *Avena nuda* were grown and one hundred sixty-four, or 94.7 per cent, were infected. These results indicate that the conditions were exceedingly favorable for the infection of susceptible plants.

The data indicate rather clearly that resistance to the smut is a dominant character and that susceptibility is recessive and, further, that these characters depend upon a single factor difference. To be sure, the number of plants is not especially large but the approximation to this interpretation is exceptionally close.

OBSERVATIONS ON THE BEHAVIOR OF THE F_3 GENERATION

Results with F_3 Families of Resistant F_2 Plants.—Naturally, no further study of the susceptible F_2 plants was made, since the floral parts were completely destroyed and no grain developed. The behavior, however, of most of the surviving sixty-one resistant F_2 plants was determined in the F_3 generation. For various reasons the progeny of nineteen of them was not studied, the behavior of the progeny of the remaining forty-two being carefully observed. The seed from thirteen of these was inoculated, germinated in sand at room temperature and later transplanted to the field where they grew to maturity. The seed of the remaining twenty-nine was also inoculated, germinated in sand with 30 per cent moisture in the constant temperature tank at 20° C. and grown to maturity in the greenhouse. Since the seed of some of these F_2 plants was hulled and that of others hull-less, the hulls from the former were removed before inoculation.

In Table II are recorded the data on the behavior of the F_3 progeny of these forty-two resistant F_2 plants. If the view that smut resistance in this cross depends upon a single factor, as indicated by the results of Table I, is correct we should find in the F_3 progeny only two classes of families, namely, those which are entirely resistant and those which are segregating with reference to smut resistance in an approximately three to one ratio. The theory also requires that the two classes of progenies, resistant and segregating, should be represented in the ratio of one of the former to two of the latter. There should be no families in which all the individuals were susceptible to the disease, since the F_2 plants carrying the factor for susceptibility have been prevented from seed formation by the parasite and consequently eliminated from producing progeny in the following generation.

It is possible, however, that one or more susceptible F_2 plants may have escaped infection and consequently their freedom from smut was not due to real resistance. As presented later, there is some evidence that this actually occurred.

TABLE II

RESULTS WITH F_3 FAMILIES OF RESISTANT F_2 PLANTS

F_2 plant		Results with *Ustilago Avenae*			F_2 plant		Results with *Ustilago Avenae*		
Number	Grain type of panicle	No. plants	No. inf.	Per cent inf.	Number	Grain type of panicle	No. plants	No. inf.	Per cent inf.
				Segregating F_3 families					
1	Naked *	19	3	15.7	120	Naked	25	7	28.0
3	Hulled	46	18	39.1	124	Hulled	24	6	25.0
4	Naked *	50	15	30.0	125	Naked *	24	5	20.8
8	"	13	3	23.0	126	" *	23	9	39.1
10	Hulled	36	18	50.0	127	Hulled	23	8	34.7
15	"	17	1	5.8	128	"	23	8	34.7
104	"	21	3	14.2	129	Naked *	18	4	22.2
105	Naked	24	5	20.8	132	Hulled	23	9	39.1
106	"	24	7	29.1	133	Naked *	25	8	32.0
107	"	24	4	16.6	135	" *	25	6	24.0
109	" *	24	4	16.6	136	Hulled	26	10	38.4
111	" *	25	5	20.0	138	"	25	3	12.0
115	" *	25	5	20.0	140	Naked *	23	4	17.3
116	" *	12	5	41.6	141	" *	23	3	13.0
117	Hulled	21	7	33.3	142	" *	22	7	31.8
				Resistant F_3 families					
2	Naked *	43	0	0	24	Naked *	15	0	0
6	Hulled	20	0	0	102	" *	23	0	0
7	Naked *	11	0	0	118	" *	26	0	0
9	" *	70	0	0	122	" *	18	0	0
16	" *	29	0	0	134	Hulled	21	0	0
17	" *	5	0	0	137	"	24	0	0

The F_2 plants are indicated on the basis of whether the panicle contains many-flowered naked-grains or few-flowered hulled-grains. The panicle of the first may also contain spikelets of the hulled type.

The * indicates that the F_3 progeny contains both panicle types.

An examination of Table II discloses the interesting fact that thirty of the F_2 families gave progeny which was segregating for resistance to smut. The percentage of infection in these

families varied from 5.8 per cent in No. 15 to 50 per cent in No. 10. The percentage of infection in the latter was rather high, in this particular progeny a total of thirty-six plants being grown, of which eighteen were infected. The average for all the families, however, is quite close to a 1 to 3 ratio. Further, the remaining twelve F_2 plants gave progeny which were entirely resistant, no infection occurring in any individual of these families; finally no families were found in which all the individuals were highly susceptible. If, on the basis of these data, we arrange the results in tabular form, we obtain the following:

	Total	Segregating	Resistant	Susceptible
Expected	42	28	14	0
Observed	42	30	12	0

We thus see that these results are in close correspondence with the data obtained with the F_2 plants.

Results with F_3 Families of Uninoculated F_2 Plants.—In addition to the F_3 progeny of the resistant F_2 plants just described, studies were made with the progenies of fifty-eight F_2 plants which had not been inoculated. Among these we would expect the appearance of three classes: (1) all the individuals susceptible; (2) all the individuals resistant; and (3) a class in which the progenies show segregation for smut resistance. Further, these three groups should appear in the ratio of one susceptible, two segregating and one resistant.

An examination of Table III reveals the fact that twenty-eight of these fifty-eight F_3 families show segregation, the percentage of infection ranging from 3.8 per cent in No. 49 to 58.5 per cent in No. 28. Further, the progeny of eighteen of the plants were pure resistants, no infection occurring in any individuals. Finally, the progeny of the remaining twelve plants may be classified as susceptible, since a large proportion of the individuals were infected by the parasite. In this group the percentage of infection varied from 81.8 to 100 per cent, all the individuals of nine of the twelve families being attacked.

The question may be raised as to whether family No. 28 should be classified in the segregating or susceptible group. The per-

TABLE III

RESULTS WITH F_3 FAMILIES OF UNINOCULATED F_2 PLANTS

F_2 plant		Results with *Ustilago Avenae*			F_2 plant		Results with *Ustilago Avenae*		
Number	Grain type of panicle	No. plants	No. inf.	Per cent inf.	Number	Grain type of panicle	No. plants	No. inf.	Per cent inf.
				Segregating F_3 families					
28	Hulled	41	24	58.5	55	Hulled	9	3	33.3
30	"	51	4	7.8	58	Naked	3	1	33.3
31	Naked *	73	15	20.5	62	" *	28	5	17.8
32	" *	19	5	26.3	64	" *	4	2	50.0
34	" *	145	36	24.8	78	Hulled	28	4	14.2
35	Hulled	62	6	9.6	81	"	36	2	5.5
37	"	44	3	6.8	88	Naked *	16	1	6.2
39	Naked *	89	23	25.8	89	" *	37	9	24.3
41	"	12	3	25.0	90	" *	69	10	14.4
48	"	8	3	37.5	145	"	24	11	45.8
49	Hulled	26	1	3.8	149	" *	14	5	35.7
50	Naked *	3	1	33.3	150	Hulled	23	4	17.3
52	"	43	13	30.2	153	Naked	24	9	37.5
53	Hulled	44	6	13.6	158	"	27	8	29.6
				Resistant F_3 families					
29	Naked *	30	0	0	80	Naked	9	0	0
38	Hulled	15	0	0	82	" *	8	0	0
42	Naked *	26	0	0	84	Hulled	4	0	0
46	Hulled	7	0	0	85	Naked *	19	0	0
54	"	8	0	0	101	" *	18	0	0
69	Naked *	35	0	0	148	" *	23	0	0
70	" *	57	0	0	151	" *	25	0	0
74	" *	12	0	0	154	" *	23	0	0
75	" *	23	0	0	159	" *	22	0	0
				Susceptible F_3 families					
27	Naked *	10	9	90.0	77	Hulled	11	9	81.8
40	Hulled	29	24	82.7	91	Naked *	18	18	100.0
47	Naked *	48	48	100.0	93	"	3	3	100.0
57	" *	35	35	100.0	147	Hulled	22	22	100.0
60	" *	7	7	100.0	152	Naked	25	25	100.0
63	" *	16	16	100.0	155	"	22	22	100.0

The F_2 plants are indicated on the basis of whether the panicle contains many-flowered naked-grains or few-flowered hulled-grains. The panicle of the first may also contain spikelets of the hulled type.

The * indicates that the F_3 progeny contains both panicle types.

centage of infection 58.5 per cent is rather low for a highly susceptible family but is equally high for a segregating one. The number of individuals grown, however, was fairly large, namely, forty-one. In order to determine to which class this family actually belongs it is necessary to study the subsequent generation which, in part, has been possible.

In tabular form the results for the fifty-eight families appear as follows:

	Total	Resistant	Segregating	Susceptible
Expected	58	14.5	29	14.5
Observed	58	18	28	12

The facts observed are in fairly close harmony with the theoretical requirements, although there are a few too many resistant families. In view of the total number of plants, however, the variation is not exceptional.

RESULTS OBTAINED WITH THE F_4 GENERATION

Results with the Descendants of Resistant F_3 Families.—As yet the F_4 descendants of only a few of the F_3 plants have been grown and consequently, the data are insufficient to draw any final conclusions as regards their behavior to *Ustilago Avenae*. However, the facts obtained are interesting in their general bearing upon the problem and are worth being noted.

In Table IV there are recorded the results obtained with the F_4 progeny from nine resistant F_3 families. In each case the seed of six different F_3 plants was inoculated and the individuals grown to maturity in the greenhouse. Seven of these progenies (Nos. 2, 6, 7, 9, 16, 17 and 24) are descended from inoculated F_2 plants, the remaining two progenies (Nos. 29 and 38) not being tested in the F_2 generation.

As noted from the table all the F_4 individuals in these progenies from the nine F_3 families were entirely resistant. More than 100 plants of each were grown and in a total of 1,025 plants not one was observed to be infected.

Results with the Descendants of Susceptible and Segregating F_3 Families.—The F_4 progeny from only one susceptible F_3 family,

TABLE IV

RESULTS OBTAINED WITH THE F_4 GENERATION DESCENDED FROM NINE RESISTANT F_3 FAMILIES

Number of F_2 plant	Results with *Ustilago Avenae*		Number of F_2 plant	Results with *Ustilago Avenae*	
	No. plants	No. infected		No. plants	No. infected
2*	113	0	17*	103	0
6*	112	0	24*	116	0
7*	117	0	29	112	0
9*	114	0	38	118	0
16*	120	0			

In each case the progeny of six different F_3 plants was grown. Those indicated by the * descended from inoculated F_2 plants.

No. 40, has been grown. In the F_3 this family gave, out of a total of twenty-nine plants, twenty-four infected, or 82.7 per cent. The seed used in growing the F_4 generation came from uninoculated F_3 plants and not from the survivors of the previous test. As seen from Table V, the individuals were highly susceptible. A total of one hundred and sixteen plants, descended from the six different F_3 individuals, were grown, of which one hundred and fifteen, or 99.1 per cent, were infected, only one plant escaping and producing abundant seed.

The F_4 progeny of fourteen segregating F_3 families was grown, the descendants of six different F_3 plants being tried in each case. Since the individual F_3 plants from which the seed was taken had not been inoculated we might expect to find in the F_4 progeny three classes represented, namely, resistant, susceptible and segregating. The F_4 descendants of family No. 10 all proved to be susceptible, one hundred and sixteen plants being obtained from the six parents, and of these, one hundred and fifteen or 99.1 per cent being infected. This family in the F_3 generation gave a percentage of infection of 50, eighteen plants out of a total of thirty-six being attacked. This of course was rather high for a segregating family; on the other hand, it was exceptionally low for a susceptible group. The evidence from the fourth generation, however, indicates that it is probably a susceptible progeny and that the inoculated F_2 plant, as well as 50 per cent of the inoculated F_3 plants, escaped infection.

The progeny of the F_3 families Nos. 3 and 28 also showed an excess of highly susceptible individuals. In No. 3 the progeny of five plants was all susceptible, eighty-five individuals being grown. The progeny from the remaining plant, however, gave 18.7 per cent infection, or three infected plants out of a total of sixteen. In the case of No. 28 the progeny of four of the F_3 plants proved to be entirely susceptible, fifty-seven plants being

TABLE V

RESULTS OBTAINED WITH THE F_4 GENERATION DESCENDED FROM ONE SUSCEPTIBLE AND FOURTEEN SEGREGATING F_3 FAMILIES

Number of F_2 plant	No. of F_4 families grown	Results with *Ustilago Avenae*			Number of F_2 plant	No. of F_4 families grown	Results with *Ustilago Avenae*		
		No. plants	No. inf.	Per cent inf.			No. plants	No. inf.	Per cent inf.
40	6	116	115	99.1	32	1	20	6	30.0
						1	18	3	16.6
1*	2	30	30	100.0		1	20	3	15.0
	1	20	5	25.0		1	20	2	10.0
	1	18	4	22.2		1	19	1	5.2
	1	18	3	16.6		1	18	0	0
	1	17	2	11.7					
3*	5	85	85	100.0	34	1	20	19	95.0
	1	16	3	18.7		1	20	8	40.0
						1	18	7	38.9
4*	2	40	40	100.0		1	18	7	38.9
	1	20	7	35.0		1	20	6	30.0
	1	20	7	35.0		1	18	5	27.8
	1	20	4	20.0					
	1	20	0	0	35	1	18	7	38.8
						1	14	5	35.7
10*	6	116	115	99.1		1	18	2	11.1
						3	52	0	0
15*	3	34	33	97.0					
	3	55	0	0	37	1	19	19	100.0
						1	19	3	15.7
28	4	57	57	100.0		1	20	1	5.0
	1	20	11	55.0		3	59	0	0
	1	19	5	26.3					
					39	1	7	7	100.0
30	3	48	47	97.9		1	19	6	31.5
	1	19	4	21.4		1	21	5	23.8
	2	36	0	0		1	20	4	20.0
						2	39	0	0
31	1	18	18	100.0					
	1	16	3	18.7					
	1	17	3	17.6	41	3	61	59	96.7
	1	19	2	10.5		1	21	5	23.8
	2	39	0	0		2	40	0	0

No. 40 was susceptible in the F_2 generation, all the others segregating. Those indicated by the * descended from inoculated F_2 plants.

grown and all being infected. The progeny from one additional plant gave a rather high percentage of infection for a segregating group, namely, 55 per cent, eleven plants out of a total of twenty being infected. The descendants of the sixth plant gave 26.3 per cent infection, or five plants out of a total of nineteen.

The remaining eleven F_3 families represented contained progenies which segregated in a ratio more or less closely approximating three to one; the percentage of infection, however, varied from as low as 5 per cent to as high as 40 per cent. Nine of these eleven groups contained progenies of plants which were highly susceptible, two of them, Nos. 32 and 35, not containing any highly susceptible group; nine also contained highly resistant progenies, Nos. 1 and 34 not containing any F_4 family in which all the individuals were resistant.

The data on these eighty-four progenies may be summarized as follows:

	Total	Resistant	Segregating	Susceptible
Expected	84	21	42	21
Observed	84	19	33	32

Both the parents were grown for direct comparison with the F_4 generation, being subjected to exactly the same treatment. The susceptible *Avena nuda* gave 100 per cent infection, eighteen plants being grown. On the other hand, no infected plants of Black Mesdag out of a total of twenty-two were observed.

Although the data are limited, it is interesting that these various groups of F_4 progenies have behaved in a manner somewhat closely approximating the requirements of a theoretical interpretation of a three to one ratio.

If we now combine the data recorded in Tables I, II and III in order to determine the proportion of resistant, segregating and susceptible F_2 plants, bringing together the facts observed on the inoculated F_2 generation with those obtained from the F_3 progeny of both inoculated and uninoculated F_2 plants, we obtain the following results:

	Total	Resistant	Segregating	Susceptible
Expected	140	35	70	35
Observed	121	30	58	33

The total of observed plants in the last line omits the progeny of nineteen inoculated F_2 plants which were not followed out in the subsequent F_3 generation. In view of the results recorded in Table II, all, or at least most of these, would probably fall in the segregating and resistant classes.

MORPHOLOGICAL CHARACTERISTICS AND SMUT RESISTANCE

It is not within the scope of the present paper to describe in detail the inheritance of the morphological characters of this cross. The two parents, as already noted, differ in a large number of features. The inheritance of such characters as many-flowered and few-flowered spikelets, which appear to be linked with naked and hulled grains, the presence or absence of awns, the color of the lemma, have been described for various oat crosses by a number of investigators. In general the facts observed in the present cross are in harmony with those recorded by Norton (**11**), Nilsson-Ehle (**9**, **10**), Zade (**19**), Surface (**17**), Gaines (**5**), Love and Fraser (**7**), Zinn and Surface (**20**), Caporn (**3**), Love and Craig (**6**), Fraser (**4**), and Love and McRostie (**8**).

I have already emphasized the fact that the F_1 plant did not show the intermediate type of spikelet as described by other workers who have studied crosses involving a many-flowered hull-less grained oat as one of the parents. However, among the F_2 plants there were several which had panicles of the so-called intermediate type. The spikelets in the terminal part of the panicle were of the many-flowered type while those at the base and inner part of the panicle were of the few-flowered hulled type. Some of the spikelets also had naked grains in the basal flowers and hulled grains in the upper. The characteristic types described by Caporn (**3**) as "hardbacks" and "semi-looses" have also been observed among the F_2 plants as well as in their progeny. It is difficult to follow out the inheritance of the presence or absence of awns, as this is complicated by the thin membranous lemma in the *nuda* type which does not appear able to support the development of a complete awn. The problem of the inheritance of lemma color is also complicated because of the fact that the thin membranous lemma of the

hull-less type does not seem to be dark in color. My own observations, however, convince me that the inheritance of the color of the lemma and of the palea are independent, for it has been frequently observed that hulled types of oats have segregated out in which the lemma was light and the palea dark as well as the more familiar types of dark lemma and palea or light lemma and light palea. It is also evident that the presence of color in the lemma is due to more than one factor, for various degrees of color may be present—gray, dark gray, light brown, dark brown, black—in the lemma of the plants.

All of my data indicate clearly that the few-flowered hulled type of spikelet is recessive and, when once segregated out, the individuals breed true for this character. On the other hand, the plants with the characteristic many-flowered spikelets may breed true or may segregate into the different types; the plants with the intermediate type of panicle all show segregation for spikelet character in the subsequent generations.

My data are sufficiently complete for comparing the occurrence of the many-flowered naked grain type of spikelet, characteristic of the susceptible parent, and also the few-flowered hulled grain type of the highly resistant Black Mesdag with resistance to smut. In Table II there are listed the F_3 progeny of thirty F_2 plants which showed segregation for smut resistance. The spikelet characters of the F_2 parents are also indicated. Nineteen had the many-flowered hull-less grain type of spikelet, the F_3 progeny of fourteen of these showing segregation for this character. The remaining eleven F_2 plants had the few-flowered hulled grain type. In the same table there are listed twelve resistant F_3 families; the F_2 parent of nine had the many-flowered-naked grain type of spikelet, all segregating in the F_3, and the remaining three had the few-flowered hulled grain type. Similar data are shown in Table III for additional F_2 plants. Here we find that the numbers of many-flowered and few-flowered F_2 plants are as follows: (1) Segregating for smut resistance—eighteen with many-flowered and ten with few-flowered; (2) resistant to smut—fourteen with many-flowered and four few-flowered; (3) susceptible to smut—nine with many-flowered and three few-flowered.

Arranged in tabular form these data appear as follows:

Behavior of F_3 progeny to smut	Total No. of progenies	Spikelet character of F_2 plants	
		Many-flowered naked grain	Few-flowered hulled grain
Segregating (Table II)	30	19	11
Resistant (Table II)	12	9	3
Segregating (Table III)	28	18	10
Resistant (Table III)	18	14	4
Susceptible (Table III)	12	9	3
	100	69	31

These data do not suggest that there is any definite linkage between the factors for the spikelet and grain characters and smut resistance.

Several types have already been segregated out in the F_4 generation in which all the individuals are similar in certain characters. Some of these are practically identical with the original Black Mesdag in spikelet and grain characters, the presence of well-developed awns, and the dark-colored lemma and palea, but which are either highly susceptible or highly resistant to smut. There have also been isolated true breeding types of the hull-less oats which seem to possess all the marked resistance of the original Black Mesdag, although there is a close resemblance in the spikelet characters between those of the susceptible parent. It is, of course, difficult to segregate out types closely resembling either parent in a number of morphological features; the differences between these two varieties are too many for a ready synthesis of the original characters. The F_4 individuals accordingly usually contain various combinations of the characters of the original parental types.

We have, however, both resistant and susceptible F_4 progenies of which all the individuals are alike as to the following characters:

1. Many-flowered hull-less grained spikelet, light-colored palea.
2. Many-flowered hull-less grained spikelet, dark-colored palea.
3. Few-flowered hulled grained spikelet, dark lemma and dark palea.

4. Few-flowered hulled grained spikelet, light lemma and light palea.
5. Few-flowered hulled grained spikelet, light lemma and dark palea.

The number of types of progenies, both resistant and susceptible, is further increased when the presence or absence of well-developed or weak awns is included. While sufficient data have not been presented to statistically establish the absence of linkage between any morphological character and smut resistance, yet it is clear that the quality of resistance may be present in an individual with various combinations of factors for morphological characters.

CONCLUSION

The data presented indicate quite clearly that, in this cross between the very susceptible *Avena nuda* L. var. *inermis* (S.N. 30) and the resistant *A. sativa* L. var. Black Mesdag (S.N. 70), resistance to *Ustilago Avenae* is dominant while susceptibility is recessive. The facts are also in close accord with the interpretation that there is a single factor difference between the two parents. It is also evident that various combinations of morphological characters and smut resistance may be obtained and a whole series of new types of resistant oats, some with hull-less and some with hulled grain, developed.

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NOTES AND BRIEF ARTICLES

Dr. J. C. Arthur, of Purdue University, Lafayette, Indiana, recently spent a few days at the New York Botanical Garden, conferring with the editor of North American Flora, regarding the publication of rust manuscript which is nearly completed.

Dr. and Mrs. N. L. Britton accompanied by Mr. Kenneth R. Boynton, Head Gardener of the New York Botanical Garden, have recently returned from Porto Rico, and the Virgin Islands, with additional collection of plants, including some fungi.

Dr. James R. Weir, Pathologist in Charge of Pathological Collections, Bureau of Plant Industry, has completed a two months' period of service with the Tropical Plant Research Foundation on a survey of sugar cane fungi in Cuba and afterwards collected and studied the diseases of tropical plants in Haiti, the Dominican Republic, and Puerto Rico.

Hon. Carlos E. Chardon, Commissioner of Agriculture and Labor of Porto Rico, was a recent caller at the New York Botanical Garden. Mr. Chardon, a graduate of Cornell University, is a trained mycologist and is collaborating in the work of preparing a check list of Porto Rican fungi, which is to be published by the New York Academy of Sciences. The main object of his visit to the states was to look after details in connection with the proposed embargo on certain Porto Rican fruits.

Mrs. Mary H. Holway, wife of the late E. W. D. Holway, recently visited the Garden to talk over matters relating to her husband's work. Mrs. Holway accompanied and assisted her husband on his last trip to South America which resulted in bringing back large quantities of valuable fungi. We understand

that these are to be carefully studied by experts in various groups, especially the rusts, and the results to be published later.

FUNGI AT LYNCHBURG, VIRGINIA

During the latter half of July, 1924, the writer made frequent excursions to the fields and woodlands in and about Lynchburg, to study trees, flowers, and fleshy fungi. The first visit to an oak grove in Rivermont afforded a surprise in the unusual abundance of the common edible species of *Chanterel*, a basketful of which was collected for the table. On the way to the mountains north of the town, several black locust trees were found infected with *Trametes robiniophila*, a white polypore first described from Falls Church, Virginia; while almost every tree of this kind in the state seems to harbor the very destructive *Pyropolyporus Robiniae*.

An afternoon spent in the spacious grounds of the Orphanage yielded a number of interesting things, among them *Russula compacta, R. foetens, R. Mariae, R. virescens; Lactaria piperata* in great abundance; *Venenarius phalloides, V. solitarius;* and several rarer species.

On July 27, I spent the day with several friends on an excursion to the westward and southward, covering over one hundred miles and making several stops for collecting fungi. We first drove due west about fifty miles, crossing Otter River and Goose Creek on old covered bridges. The day was fine and the roads at their best. *Coreopsis, Saponaria*, and the towering stalks of the common mullein brightened the roadsides. Blackberries and huckleberries were unusually common; while wild plums, peaches, and early apples were ours for the picking.

The most abundant fungus noticed was *Lactaria piperata;* the handsomest, *Venenarius solitarius*, which could be seen in conspicuous ghostly groups as we drove through the woods; while the most interesting was probably *Ceriomyces Betula*, with tall, grooved stipe and reddish, viscid pileus. Another rare southern species found, collected by me previously only at Blacksburg, Virginia, was *Vaginata parcivolvata*, a colored plate of which appears as the frontispiece of Marshall's book. Among other specimens collected were: *Lactaria lactiflua, Russula*

nigricans, *Venenarius Frostianus*, *Pholiota Johnsoniana*, *Pluteus cervinus*, and *Strobilomyces strobilaceus*.

Lunch was eaten by a spring beneath a shady canopy of red maple, white ash, black locust, persimmon, and dogwood branches, with thickets of blackberries close at hand and three June-apple trees in sight. We then swung southward to the fertile meadows of Staunton River and drove for a mile or more between hedgerows of trumpet creeper (*Tecoma radicans*), thickets of alder, and swamps filled with cattails. Near Altavista, about twenty-five miles from Lynchburg, we found another very attractive spring at the foot of a hill beneath beech and maple trees. Here I botanized while the watermelon was cooling and collected a number of fungi not previously seen on the trip, among them *Chanterel cinnabarinus*, *Hypomyces* on *Venenarius solitarius*, the dark form of *Venenarius phalloides*, *Vaginata vaginata*, *Tyromyces semipileatus*, and *Coltricia cinnamomea*.

From this point, we went to Lynch's Station, where I was born, then turned northward over a good road and reached Lynchburg just at dusk.

W. A. MURRILL